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ABSTRACT

Basic research in speech and the lateralization of language is shown to illuminate the problems of reading and some of its disabilities. First, it is pointed out how speech for the ear differs from reading, or language for the eye. Perceiving speech is easy because, as members of the human race, we all have access to a special physiological apparatus that decodes the complex speech signal and recovers the segmentation of the linguistic message. Reading is hard because the phonemic segmentation, which is automatic and intuitive in the case of speech, must be made fully conscious and explicit. The syllabic method supplemented by phonics is suggested for remediation of segmentation problems. Second, it is posited that since the sounds of speech are processed differently from nonspeech sounds, the two should not be diagnosed and remediated interchangeably. Third, it is shown that the relationships among cerebral lateralization for language, handedness, and poor reading can now be studied more meaningfully because of the recent development of new techniques. (Author/WR)

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SPEECH AND LATERALIZATION OF LANGUAGE

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**BASIC RESEARCH IN SPEECH AND
LATERALIZATION OF LANGUAGE:
SOME IMPLICATIONS FOR READING DISABILITY¹**

ISABELLE Y. LIBERMAN, PH.D.

* * * *

Abstract

Basic research in speech and the lateralization of language is shown to illuminate the problems of reading and some of its disabilities. First, it is pointed out how speech, or language for the ear, differs markedly from reading, or language for the eye. Though the sounds of speech are a very complex code and the optical shapes of written language are a simple cipher or alphabet on the phonemes, we all perceive speech easily but read only with difficulty. Perceiving speech is easy because, as members of the human race, we all have access to a special physiological apparatus that decodes the complex speech signal and recovers the segmentation of the linguistic message. Reading is hard because the phonemic segmentation, which is automatic and intuitive in the case of speech, must be made fully conscious and explicit. The syllabic method supplemented by phonics (used with certain reservations) is suggested for remediation of segmentation problems. Second, it is posited that since the sounds of speech are processed differently from non-speech sounds, the two should not be diagnosed and remediated interchangeably. Third, it is shown that the relationships among cerebral lateralization for language, handedness and poor reading can now be studied more meaningfully because of the recent development of new techniques.

A truism often heard in the opening lecture of graduate classes in education is that we have few answers to the problems that beset us, only questions. In the field of reading, the difficulty may be owing at least in part to our impatient attempts to find immediate solutions for the teacher and the student in the classroom, and our consequent neglect of basic research. I should like to suggest today how knowledge of basic research in related disciplines may lead to clues for improving beginning reading instruction and the lot of the disabled reader—if only by affording us a deeper understanding of the reading process.

* * * *

¹ Paper based on a talk given at the Twenty-first Annual Conference of The Orton Society, Washington, D.C., November 14, 1970. Dr. Liberman is Professor of Education, University of Connecticut, Storrs, Connecticut.

The Poor Reader: Does He Have A "Language Disability"?

For over 75 years, much of the research in reading has been aimed at finding how the poor reader differs from the good reader. Thus, many studies have correlated the reading level of the child with various indices of abilities or attributes which had been found to be defective in clinical studies of individual readers. These have in the main led to the conclusion that there are great individual differences among poor readers, and that no single indices are typical of a large body of poor readers. The most consistent exceptions have involved tasks which are strongly language-related, or actually reading-related. I mean such tasks as oral word rhyming, oral vocabulary, word naming, letter-naming, word-recognition, name-writing and the like (De Hirsch, 1966; Doehring, 1968). Many, though not all, are essentially miniature reading and writing tasks. Of course, we should not need a giant correlational study to prove that reading is related to reading, nor should we be surprised to find that reading has something to do with language (though many remedial methods in current use seem to reflect this message only dimly).

It is certainly fair to say that in some sense the potentially poor reader frequently has language problems. But in what sense do we mean this? Given a child up to the age of eight—before his ability to read would make any substantial difference in his ability to speak—what is there about the language ability of the potentially poor reader that is different from that of the potentially good reader?

Data derived from two areas of basic language-related research seem to me to offer promising leads to these and other questions about reading—both the process and the disability. The two areas of basic research include speech perception and the lateralization of language.²

I think we would all agree that poor readers can speak and listen to language far better than they can read or write it. From this point of view, to describe their problem as a "language disability" is to use the term very loosely indeed. Surely, if we could somehow teach them to write and read as well as they can speak and listen, we would not be concerned about their "language disability", if any. Speaking and listening, then, are a necessary condition for reading, but not a sufficient condition. It may be useful, therefore, to ask what we know about the difference between speaking and listening on the one hand, and reading and writing on the other.

²Much of the work I will report was done by researchers at the Haskins Laboratories. I should like to express my indebtedness to my husband, Alvin M. Liberman, and to a colleague, Donald P. Shankweiler, both of whom are members of the Haskins group and also professors of psychology at the University of Connecticut, for the assistance they have given me. Research sources other than the Haskins group are credited as they appear.

Language for the Ear and for the Eye

We all know that human language is distinguished from other communication systems by the fact that it is phonemic. That is, all human languages are composed of commutable segments which have no meaning in themselves. It is clear that these phonemes can be transmitted either by ear or by eye—that is, by spoken or written language.

Speech, but not Reading, is Natural to Man

We are all aware that speaking (or language for the ear) has a strong priority over reading (or language for the eye). The evidence for this is, of course, part of our common knowledge. Speech is universal, while reading is rare among the people of the world. Speech is first in the evolution of man, while reading is second; reading is, moreover, a comparatively recent development in man's history. It is also relevant to observe that the alphabetic method of reading and writing has been invented only once, which suggests that it is, in some important sense, unnatural. Speech is also first in the history of the individual while reading comes second. Speech is, moreover, remarkably easy for humans to acquire. Infants are already listening discriminatively to speech by the age of one month (Eimas, Siqueland, Jusczyk & Vigorito, 1970) and most two-year-olds are beginning to speak intelligibly themselves. Speech apparently requires no tuition, only an input of linguistic data and an opportunity to interact with those data. In contrast, reading is difficult and is not ordinarily acquired unless it is taught.

The Sounds of Speech are Uniquely Natural

Moreover, as Mattingly and Liberman (1969) have pointed out, though sound is the only universal vehicle for the transmission of language, only one set of sounds, the sounds of speech, will work efficiently to transmit language. Morse code, which is an artificial sound alphabet, cannot be transmitted at rates much higher than five or six characters a second, even after years of practice. Other sound alphabets which were devised for use with reading machines for the blind seldom reached perceptual rates of more than two characters a second, though the subjects were often well practiced and highly motivated. At rates far below those which are possible in the perception of *natural* speech sounds, the output of *artificial* sound systems become an unidentifiable blur to the perceiver. On the other hand, it is hardly necessary to remark that many alphabets—Cyrillic, Hebraic, Arabic, Roman, for example—are available and equally efficient for use in transmitting language for the eye, though none is as natural or easy as the sounds of speech.

The point I have been trying to make, then, is that speech and its sounds are somehow basic to language in a way that the written language and its optical shapes are not. The phonemic segments of the language are transmitted easily and universally by the sounds of speech and by no

others. Thus, the advantage is not with *sounds* in general, but very specifically with the sounds of *speech*. Optical shapes representative of language—the written letters of the alphabet—will also work to transmit the phonemic segments, but they are a very recent invention in the history of man, are not used universally, and are relatively hard to use. With a few special and quite understandable exceptions, all human beings can speak and listen, but only a relatively few can read and, of that group, fewer still read well.

Transmission of Language by Speech Sounds and by Alphabetic Writing

We all know that speech and reading differ, as I have said they do, in the ease with which people master the processes. However, if our thinking has been conditioned by traditional views of speech perception and reading, we may not have considered this to be a productive contrast to make. The traditional view includes two common assumptions about the transmission of language by ear and by eye which tend to obscure the important differences between these processes. Both of these assumptions are brought into serious question by recent research on speech.

The first false assumption is that the phonemic segments of language are transmitted individually by the sounds of speech, just as they are transmitted individually by the optical shapes of the alphabet. In this view, the sounds of speech bear a simple one-to-one relation to the phonemic segments, much as the optical shapes of the alphabet (orthographic variations aside) so obviously do. The word "bag", for example, which is represented in alphabetic writing by three letters, one for each of the perceived phonemic segments, is assumed to be represented, similarly, in speech by three discrete sounds. In this traditional view, then, whether the segments are represented by sound or by optical shape, the task for the perceiver would be basically the same, different only in that it is carried out in a different mode—in the auditory mode in the case of speaking and listening, and in the visual mode in reading and writing.

Acoustic cues for the perception of speech. Let us see now in what ways this assumption may be false. Figure 1 shows at the top a speech spectrogram of the utterance, "Never kill a snake". A speech spectrogram is, of course, a visual display of the analyzed acoustic signal. Time is represented on the horizontal axis; frequency in cycles per second is represented on the vertical axis. The dark areas represent concentrations of acoustic energy at different frequencies for varying periods of time. As you can see, the spectrogram is a very "busy", muddy display.

People at Haskins Laboratories, New Haven, Conn., undertook to discover which aspects of this very complex signal carry the essential linguistic information. For this purpose, they developed techniques for converting spectrograms, including hand-painted versions, back into sound (Cooper, 1950, 1953; Cooper, Liberman, & Borst, 1951). Their aim

was to find the more general nature of the relation between the acoustic signal as seen in the spectrogram and the phonemic message, which is what one perceives auditorally (Liberman, Cooper, Shankweiler, & Studert-Kennedy, 1967; Mattingly & Liberman, 1969).



Fig. 1—At the top, a spectrogram of the phrase, "Never kill a snake"; at the bottom, a simplified hand-painted spectrogram which is sufficient, when converted into sound, to produce an intelligible version of the same phrase. (Reprinted by courtesy of the Haskins Laboratories. All copyright rules apply.)

At the bottom of Figure 1 is a schematic painted spectrogram which represents a considerable simplification of the acoustical signal with the greater part of the signal discarded. The Haskins group found by trial and error that simplified spectrograms of this kind are nevertheless sufficient to produce intelligible speech. They proceeded, then, over a period of years

to investigate this problem more systematically and succeeded in isolating the acoustic cues for all the various phonemic segments.³

Acoustic cues are not an alphabet on the linguistic message. Figure 2⁴ shows examples of the essential acoustic cues for the universal stop consonant /d/ and also important general characteristics of the relation between the sound signal and the perceived message. The schematic patterns shown are sufficient for the synthesis of /d/ before /i/ and /u/.



Fig. 2—Simplified spectrographic patterns sufficient to produce /di/ and /du/. Reprinted from an article by A. M. Liberman in the October 1970 *Cognitive Psychology*. Copyrighted by Academic Press, October 1970.)

The black lines represent formants, i.e., concentrations of acoustic energy within a restricted frequency region. At the left of each pattern are the rapid changes in frequency known as the formant transitions. These have been found to be cues for the perception of consonants. The transition of the *first*, or lower, formant is the cue for the voiced stops—/b,d,g/. It carries the information about the *manner* and *voicing* of the consonant. This transition would be the same whether the syllables were /bi,bu/, /gi,gu/, or, as they are here in Figure 2, /di,du/, because /b,d,g/ are all voiced stop consonants.

³See Liberman et al., 1967, for a general review of these findings, together with references to the original experimental papers on which they are based.

⁴Figures 2 and 3 are taken from a recent article by A. M. Liberman (1970) and are reproduced with the permission of the author and Academic Press, the publishers of *Cognitive Psychology*. All copyright rules apply.

The *second* formant transition, which is the part of the pattern circled in the upper formant, has been found to be the important acoustic cue for the perception of consonants according to their *place* of production. That is, in the case of stop consonants, it distinguishes /b/ from /d/ from /g/. In this figure, the second formant transition contains the particular cue that causes the listener to hear /d/.

Now, in both syllables, /di/ and /du/, the /d/ sound heard by the listener is exactly the same. But the acoustic cues are very different in the two cases. In /di/, the second-formant transition rises from approximately 2200 cps to 2600 cps; in /du/, it falls instead from 1200 to 700 cps. Moreover, if one tries to separate these critical second-formant transitions from the context of the rest of the pattern and sound them in isolation, one does not get the /d/ sound at all. One gets non-speech instead: a high-pitched rising whistle for /di/ and a low-pitched falling whistle for /du/. *Outside the total pattern, the formant transitions sound very different from each other and neither of them sounds anything like /d/* (Liberman et al., 1967; Liberman, 1970).

We see, then, two related characteristics of the speech code: first, the acoustic cue for the same perceived consonant is different in two different vowel contexts and, second, there is no acoustic segment corresponding to the consonant segment /d/, for example. We cannot isolate the /d/ segment in the acoustic signal, because the second formant transition which is the essential cue for /d/ is always carrying information at the same time about both segments, the consonant and the vowel.

Successive segments of the message are complexly encoded in the acoustic signal. Figure 3 demonstrates more clearly how information about successive segments of the message is carried simultaneously by the same part of the speech signal. At the top are the perceived segments in the syllable "bag". At the bottom is a schematic spectrogram sufficient to produce that syllable. The figure shows how the segments which are experienced as separate at the perceptual level are intertwined in the sound stream. The vowel /æ/ is not limited to a medial position in the acoustic signal, as it seems to be at the perceptual level, but, rather, covers the entire length of the syllable. If the syllable were "big" instead of "bag", the second formant would be different from the beginning of the syllable to its end, not just in the middle position, as it is in the perceived message. Similarly, information in the acoustic signal about the stop consonant /b/ continues well beyond the middle of the signal. If the syllable were "gag" instead of "bag", the second formant would change throughout the entire section subsumed under the segment /b/. Moreover, the center portion of the acoustic signal is obviously providing information not just about the vowel /æ/ but also about all three perceptual segments at once (Liberman, 1970).

All of this explains the failure of early investigators (Harris, 1953) to find the building blocks of real speech by cutting tape recordings into phonetic segments and then recombining the segments to produce new words. They could not do it, because, with one or two exceptions like steady-state vowels and parts of certain fricatives (Liberman et al., 1967), the perceived segments are not found as segments at the acoustic level at all.

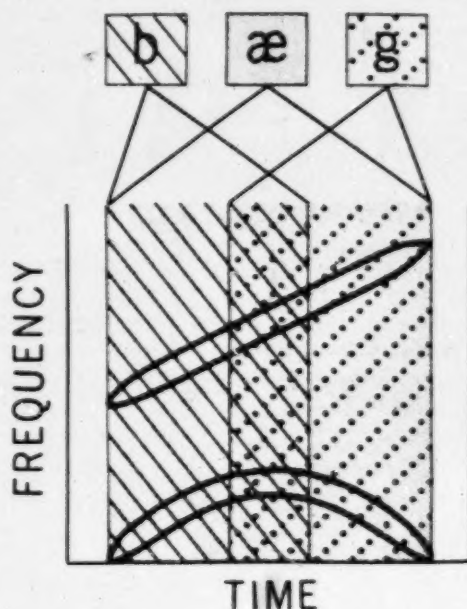


Fig. 3—Schematic spectrogram illustrating the simultaneous transmission of successive phonemic segments on the same part of the speech signal. (Reprinted from an article by A. M. Liberman in the October 1970 *Cognitive Psychology*. Copyrighted by Academic Press, October 1970.)

Now we can get back to our original statement that the sounds of speech are not a simple alphabet or cipher on the phonemes as are the optical shapes of the written language. The sounds of speech are instead a very complex code. In this complex code, information about successive phonemic segments is transmitted simultaneously, not successively in strings as it is in the written language. For this reason, it is impossible to separate out discrete phonemic segments in any representation of the acoustic sound pattern.

The Poor Reader's Language Problem: Is it Auditory?

The Complex Speech Code is Handled Intuitively

When we consider again the child who speaks and listens so much better than he can read, we are faced with an interesting paradox. He can easily master the complex speech code and yet cannot master the relatively simple alphabet of written language. If speech does not appear complex to the human being who listens to it, it is presumably because he has ready access to the special neurophysiological apparatus necessary to handle it. There is now a great deal of evidence that such special processing equipment does exist as part of our human capacity for language. Later in this paper, I shall describe just one aspect of that evidence. Meanwhile, we can observe that, as is the case with other biological processes that are deeply a part of us, we do not have to think about the process of speech in order to perform it, any more than we have to think about the process of walking in order to walk.

The Simple Alphabetic Cipher Requires Explicit Analysis of Language

If we now ask what the child is required to do in reading, we find a very different situation. There is, as we have said, a very simple relation between the alphabetic shapes and the linguistic message, but the child can take advantage of that relationship only if he explicitly analyzes and understands the segmentation of the message. Seeing the written word, being able to discriminate the individual optical shapes, being able to read the names of the three letters, and even knowing the individual sounds for the three letters, cannot help him in really reading the word "cat" (as opposed to memorizing its appearance as a sight word), unless he realizes that the word "cat" in his vocabulary has three segments. Before he can map the visual message to the word in his vocabulary, he has to be consciously aware that the word "cat" that he knows—an apparently unitary syllable—has three separate segments. His competence in speech production and speech perception is of no direct use to him here, because this competence enables him to achieve the segmentation without ever being consciously aware of it. (At the higher levels of language, similarly, one need not be consciously aware of the rules of grammar in order to produce grammatical speech.)

It seems reasonable, then, to suppose that the problem of this child who cannot read may not be, as is so commonly assumed, a problem in speech perception, or indeed, in auditory perception at all. The intuitive and automatic segmentation he carries out in speech perception must be made quite conscious and explicit if he is to read; many children may find that extremely difficult. If so, what we are dealing with is a cognitive problem, not a problem of visual perception, auditory perception or speech perception as such.

Implications of Speech Research for the Remediation of Reading Problems

The time-honored hypothesis offered when a child cannot understand that the components /k/ /æ/ /t/ form the word "cat" is that his difficulty lies in defective auditory perception or, more specifically, in not being able to blend sounds into words. One time-honored procedure for correcting this difficulty is to teach blending. I think you will agree with me that blending as either an explanatory or a remedial concept is now open to question. The word "cat" is not a blending of the sounds /k/ /æ/ /t/, if by blending one means a kind of merging of a string of consecutive sounds. It is clear that /k/ /æ/ /t/ merged together consecutively do not produce the word "cat". In speech, information about these three segments is encoded into a single sound, the syllable.

As might be expected, then, I would disagree with writers in the field (Johnson & Myklebust, 1967) who classify children with problems in phonetic analysis and synthesis as "auditory dyslexics" who have "numerous auditory discrimination and perceptual disorders which impede use of phonetic analysis [p. 174]." These writers themselves note that the spoken language of the children so classified "generally is good". I would say that if the spoken language of the child is "generally good" and if he can respond appropriately to the speech of others, one cannot ascribe his difficulties with phonetic analysis and synthesis to poor auditory discrimination and perception. If he can hear and speak the words well, then his difficulty with segmentation is cognitive, not auditory.

Phonic, ideovisual or syllabic method? I would agree that an elemental or phonic approach may be difficult for the child who cannot do phonetic analysis and synthesis, but I would strongly question the usual solution, which is to teach a sight vocabulary first—to teach by an ideovisual method, as it is called. If the child is indeed having difficulties with phonetic analysis and synthesis, then it would seem unwise to keep secret from him the relationship between the component parts of the spoken and written word. The sight method does just that, when it proposes to teach the child to read by first teaching him to associate a certain whole spoken word with a particular whole printed design.

As I see it, it might be wise, instead, to incorporate a type of syllabic approach into both beginning reading and remedial instruction. In this method, the component elements would not be treated separately as /k/ /æ/ /t/, but their identity would be clarified by the ordered use of phonetically regular syllables as suggested by Bloomfield (Bloomfield & Barnhart, 1961) and Fries (1962). By using the method of minimal contrasts and changing only one segment at a time in the syllables presented for study (e.g., "fat" and "mat", "fan" and "man"), one can illuminate the phonetic analysis of words from the start of reading instruction.

I am not prepared to say that analytic breakdown of words into their phonemes should not be used at all, but only that the ordered syllabic approach should also be used, because it conforms so much better to what we know about speech and language. And, moreover, if the phonic method is used, I would consider it important for the teacher to understand that when she uses the blending aspect of the instruction, she is not training the child's auditory perception of speech sounds. To the extent that she is helping the child at all, she is probably making it easier for him to achieve the conscious awareness of phonemic segmentation that he needs if he is to match the written version of the word to the spoken form already stored in his head.

Why vowels may present special problems. There is yet another result of speech research that may enlighten us about a difficulty commonly encountered in learning to read. A great deal has been made of the difficulties of the orthography, particularly in reference to vowel representation. There is, of course, no question that beginning readers find vowels more difficult to master than consonants. Every teacher can testify to this. Speech research indicates that there may be reasons for this that are not obvious on the surface. We learn from speech research that whereas consonants are distinctively categorical in both speech production and perception of speech, vowels are continuous and variable (Liberman et al., 1967). There is nothing between /b/ and /d/. There is only a /b/ and a /d/. When the acoustic cues for producing a /d/, for example, are changed in the direction of /b/, let us say, what you hear is either /b/ or /d/, never something in between. Consonants, then, and particularly the stop consonants (/b,d,g/ and /p,t,k/), are not regions lying along a continuum. They are categorical in the sense that they are either one consonant or another. Vowels, on the other hand, change continuously, like the pitch or loudness of tones. They do not fall into neat compartments the way most consonants do. Shankweiler has suggested (1967) that our tendency to perceive consonants categorically probably makes it easier for us to learn to associate them with graphic symbols. Similarly, the continuous nature of vowels may make it harder for us to learn their correspondences and may even account for their multiple spellings in the orthography of the language. Perhaps while consonants can best be taught by the syllabic method, vowels should be separated out for additional phonic study.

The Lateralization of Speech and Non-Speech Sounds

Earlier I said that there are at least two false assumptions about speech which tend to confuse our thinking and reading. The first, which

I have dealt with in the preceding sections, is that speech is a simple cipher on the phonetic message. The second, which I propose to discuss now, is that the process involved in the perception of speech sounds is the same as that in the perception of non-speech sounds. The traditional view here is that all sounds are acted upon by the brain in much the same way, whether they are speech sounds, or, say, household noises like the jangling of the doorbell or the crackling of paper. As I said before, one would expect, in view of the complex nature of the speech code, that we would need very special devices in order to process or decode it, and that the mechanism of speech perception would be very different from that involved in the perception of other sounds. Some of the most compelling evidence which shows that the processing of speech sounds is indeed very special and quite different from that of non-speech sounds comes from research in cerebral lateralization (the term "lateralization" here refers to the tendency of one side or hemisphere of the brain to take over certain functions).

Auditory Rivalry Technique Tests Cerebral Lateralization of Language

It has long been known that language disabilities of various kinds usually accompany injury to certain parts of the left cerebral hemisphere; injury to corresponding parts of the right hemisphere produces no such disruption of linguistic function. About ten years ago, a psychologist in Canada, Doreen Kimura, developed a bloodless, relatively simple, and potentially quite analytic method of studying lateralization of speech and non-speech processing (Kimura, 1961). In her method, the investigator presents two different stimuli simultaneously to the two ears by means of stereo earphones. This "dichotic" presentation sets up a kind of rivalry between the two ears. When the subject is asked to report what he has heard, it is found that more stimuli are correctly identified from one ear than the other. Which ear wins out in the rivalry—that is, which one provides the greater number of correct answers—will depend on the kind of stimuli that have been used.

Many investigators have since found that when the sounds presented are verbal, there is a right ear advantage. This is true whether the stimuli are digits, words, or simple consonant-vowel nonsense syllables (Kimura, 1961; Shankweiler & Studdert-Kennedy, 1967). On the other hand, when the sounds presented are non-speech sounds of any kind (melodies, environmental noises, sounds made by common objects, animal sounds, etc.), they all produce a left ear advantage (Kimura, 1964; Knox & Kimura, 1970). Moreover, these effects are obtained in children as young as five years old, whether the method of report is verbal or non-verbal—that is, whether the child indicates what he has heard by repeating it verbally or by pointing to a picture of it or to the object itself (Knox & Kimura, 1970).

Speech Sounds and Non-Speech Sounds are Processed Differently in the Brain

The implications of these findings for the study of the lateralization of language are provided by current knowledge of the actions of the auditory pathways. While each ear has representation in both hemispheres, the contralateral representation is stronger than the ipsilateral (Rosenzweig, 1951). Moreover, there is evidence that when competing signals are presented to the two ears, the ipsilateral pathways are inhibited (Milner, Taylor, & Sperry, 1968). Therefore, the interpretation of the right-ear advantage for speech and the left-ear advantage for non-speech is that speech sounds require processing in the left hemisphere, while non-speech sounds need to be processed in the right.

The fact that the sounds of speech are processed in one side of the brain and the sounds of non-speech in the other, strongly supports the assumption that they are processed in different ways. It is obvious that speech sounds must undergo some sort of auditory processing, of course—if an individual is deaf to sounds, he will not be able to hear speech—but it appears that the decoding of the complex speech code requires, in addition, physiological apparatus specialized for that purpose. It is also of interest that this apparatus is on the same side of the head as the apparatus which processes the syntactic and semantic aspects of language (Shankweiler et al., 1967). This suggests again that speech is an integral part of language.

Remedial Implications of the Difference between Speech and Non-Speech

The different processing required by the two kinds of sounds has practical implications for reading remediation. If one had strong evidence that a child really did have deficits in the perception of speech sounds, one would not necessarily expect to improve his skills in perceiving speech by first giving him training in discrimination or identification of non-speech noises, as is often done in remedial work. Sounds do not range on a single continuum from simple environmental noises to speech. If the child is not required to respond to speech, he is not functioning in the speech mode and therefore is not using the processing required in speech. Speech processing goes beyond that required in the discrimination of non-speech sounds, and is carried on in a different part of the brain mechanism.

The Poor Reader: Is He Weakly Lateralized?

We have said that speech and language are lateralized, and that perception in the speech mode is primarily in the left hemisphere. To the extent that reading taps into the linguistic process, laterality may well be

involved in reading as well. Why people who are lateralized well enough to speak and listen might not be lateralized well enough to read is not presently known. But weak cerebral lateralization has been implicated as a correlate of poor reading since the pioneering work of Orton in the twenties (Orton, 1925), who drew this conclusion in part from his clinical observations of the prevalence of uncertain handedness (motor intergrading) among children with reading problems (Orton, 1937). Orton distinguished two separate questions here.

The first is whether children who cannot read well are indeed weakly lateralized for language. The other is whether handedness is an adequate indicator of brain lateralization for language.

Until recently, the only method readily available for judging lateralization for language was indirectly through such means as the testing of handedness and other peripheral preferences. Now, for research purposes, the auditory rivalry test provides a way of measuring brain lateralization for language more directly and with an independently validated technique (Branch, Milner & Rasmussen, 1964). Studies using the auditory rivalry technique to explore the lateralization of children who are good and poor readers are as yet limited in number and inconclusive in results (Sparrow, 1968), but should in the future provide answers to the first question (Liberman, I., Shankweiler, & Orlando, in progress).

As to the second question, concerning the use of handedness as an indicator of language lateralization, handedness has long been known to be related in some manner to language lateralization (Zangwill, 1960). However, we need to know more about the exact nature of the relationship, particularly in the case of self-classified left-handers and ambilaterals. In studying this relationship, one must take into account the fact that handedness is not an either/or proposition, but, rather, a continuous variable (Orton, 1937; Benton, Meyers, & Polder, 1962; Annett, 1970) and the fact that the strength of handedness in various tasks is particularly variable in left-handers (Humphrey, 1951; Benton et al., 1962; Satz, Achenbach, & Fennell, 1967).

The relation between handedness and language lateralization has been studied in a doctoral dissertation recently completed at the University of Connecticut (Orlando, 1971), using left- and right-handed children as subjects. The results suggest that the relationship can be measured more meaningfully when *both* handedness and language lateralization (as measured by the auditory rivalry test) are regarded as continuous variables rather than as dichotomies. In addition, the study indicates that the relationship is strengthened when handedness is measured in terms of relative proficiency on manual tasks, rather than in terms of manual preferences. Under these conditions, it is found that handedness and language lateralization are, in fact, strongly correlated, even in self-classified left-handers. Moreover, the results of the auditory rivalry test correlate more highly with the overall (joint) measure of handedness than does any single handedness task. This type of study has yet to be

carried out in such a way that the results can be made to bear on the differences, if any, between the poor reader and the good reader, though some data, as yet unanalyzed, are already available (Shankweiler, Liberman, I., & Orlando, in progress).⁵

Summary

To summarize, I have tried to point out how basic research in speech and language might illuminate some of the questions we have about reading and its disabilities. The first point was that speech is basic to language in a way that reading is not. We cannot have language without speech but we can and do have language without a written form that can be read. Speech is natural to us; reading and writing are not.

The second point I tried to make was that the sounds of speech are a very complex code and the optical shapes of the written language are a relatively simple alphabet on the phonemes, yet most of us have no difficulty with the speech code while many are unable to read. This is because we have special apparatus that enables us to deal easily and intuitively with language as received by the ear despite the great complexity of the process, but we need something more in the way of a conscious, cognitive analysis of the phoneme structure of language if we are to read. When a child has difficulty in reading because he cannot segment the words and syllables of his vocabulary into their constituent phonemic elements, the problem would seem to be a cognitive one, not a matter of visual or auditory perception.

The third major point I tried to make was that speech perception involves considerably more than auditory perception of non-speech sounds. Speech sounds and non-speech sounds are processed by different mechanisms in different parts of the brain and cannot be diagnosed or remediated interchangeably.

The lateralization of function in the brain brought me to the fourth point: the relation of language lateralization to reading disability, and its corollary, the relation of language lateralization to hand preferences and proficiency. Adaptations of a new method of measuring brain lateralization, the auditory rivalry test, promise to provide answers to the first question and have already afforded meaningful directions for further

⁵ A study of great interest in this regard was recently published by Bryden (Bryden, N. P. Laterality effects in dichotic listening: relations with handedness and reading ability in children. *Neuropsychologia*, 1970, 40, 443-450). He provides suggestive evidence that boys with speech and motor functions oppositely lateralized (dominant hand opposite to dominant ear) have a higher proportion of poor readers than those who show the typical uncrossed pattern (dominant hand same as dominant ear). His method of analyzing the data in terms of this kind of "crossed dominance" opens the way for further productive exploration of the interrelationships among language and motor lateralization and reading. Additionally, this study provides interesting data concerning sex differences, the developmental progression of lateralization and the relation of the two to reading acquisition and disability.

exploration of the second. Another productive new approach is to consider both handedness and brain lateralization for language as continuous rather than dichotomous variables.

My general message was that what is known from basic research in speech and laterality can lead to new hypotheses about the problems of the beginning reader and the poor reader. I hope you will agree that these kinds of research may bring us closer to solutions for these vexing problems than we have managed to come after so many years of product-oriented investigations.

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